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MOISTURE IN WHEAT AND MILL PRODUCTS.

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INTRODUCTION.

In November, 1914, investigations were begun by the Department of Agriculture at Kansas City, Mo., in cooperation with several flour mills for the purpose of obtaining further information concerning the relative importance of moisture in the wheat kernel from the standpoint of milling. The flour-producing capacity of the mills cooperating in this work ranged from 500 to 3,000 barrels per 24 hours. The investigations, while not of sufficient scope to establish any definite conclusions, are of interest in so far as the results obtained disclose conditions present in the particular cases examined.

In obtaining the samples used in connection with these investigations, great care was exercised that each would be as nearly as possible representative of the particular lot or stream of stock sampled. Upon obtaining the samples they were immediately placed in airtight containers and sealed up until the time of determining the moisture content, which determinations were made in every instance within a week after the samples were drawn. In the case of the wheat samples, their moisture content was determined by use of the Brown-Duvel moisture tester, and in the case of the other samples

(flour, feed, and other mill products), the method used was that of drying to constant weight a small portion of the sample in a water-bath oven, at the temperature of boiling water.

MOISTURE REQUIREMENTS OF WHEAT FOR MILLING PURPOSES.

At the beginning of the process of milling, the miller gives much consideration to the question of the moisture content of his raw material. He knows that in order to secure the highest yields of flour and to insure its greatest purity, the pericarp or outer coatings of the wheat kernel at the time of grinding must be of a certain toughness, and the endosperm, or inner part, of a certain mellowness. The degree to which these properties are possessed by the different parts of the kernel is influenced largely by the amount of moisture present.

Wheat when received at the mill is seldom, if ever, in the best condition for milling, its moisture content being too high, too low, or not properly distributed throughout the kernel. To acquire the right moisture content for the outer and inner parts of the kernel, thereby insuring the best possible milling condition for different wheats, requires the application of various methods of tempering. These methods may consist of a single, or successive, or of combined applications of water, heat, or steam, working through a period of time, ranging from a few minutes to as much as 36 hours, in order that the moisture may be properly distributed within the kernel.

Dry climates and dry seasons naturally produce wheat of low moisture content, and damp climates and wet seasons produce wheat of high moisture content. There is, moreover, often considerable range in the moisture content of wheat during any given season and in any one locality. Moisture determinations of samples obtained from more than 5,000 cars of wheat, which were made by this department at Kansas City, Mo., during the years 1910 to 1914, inclusive, showed a range in the content of that factor from 7.4 per cent to 22 per cent. The fact that the moisture content of wheat may vary so greatly is evidence that the problem of properly tempering wheat is a complicated one.

AMOUNT OF MOISTURE ADDED TO WHEAT DURING TEMPERING.

In Table I is shown the percentage of moisture contained in wheat before and after cleaning and tempering as found from moisture determinations made on a series of samples secured from five different mills. The wheat of each mill was of similar class (hard red winter) and grade, and contained, at the beginning of the tempering process, approximately the same percentage of moisture. Different amounts of water, however, were added by each mill. The difference in moisture content of tempered and untempered wheat as shown in this table indicates the change in that factor which resulted from

cleaning and tempering, but does not represent the entire amount of moisture added.

TABLE I.—*Moisture content of hard red winter wheat before and after cleaning and tempering, as found at five mills.*

Date sampled.	Mill No. 1.		Mill No. 2.		Mill No. 3.		Mill No. 4.		Mill No. 5.[1]	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1915.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Nov. 30	14.00	16.15	13.95	15.50	14.00	15.10	13.40	14.35	13.20	14.15
Dec. 1	14.20	16.70	13.60	15.60	(2)	(2)	12.70	13.85	12.75	14.40
Dec. 2	13.20	16.40	13.65	15.30	14.15	14.50	14.35	15.50	13.05	14.65
Dec. 3	13.50	16.40	13.95	16.25	13.75	15.00	13.35	14.10	13.20	14.45
Dec. 4	14.15	16.70	13.80	15.80	14.65	15.75	13.10	14.95	12.85	14.10
Dec. 6	(2)	(2)	13.75	15.95	14.50	15.60	13.85	14.20	13.60	14.00
Dec. 7	13.85	16.35	13.40	15.70	14.15	15.20	13.95	(2)	13.00	14.30
Dec. 8	(2)	16.20	13.05	15.20	13.65	15.20	13.50	14.15	13.55	14.15
Dec. 9	13.85	15.50	12.90	15.10	14.00	15.00	13.00	14.30	13.20	13.40
Dec. 10	14.00	16.35	13.85	15.85	13.80	14.55	13.30	14.20	13.15	13.55
Dec. 11	13.65	16.35	13.75	15.05	14.00	14.90	14.55	15.40	13.20	13.65
Dec. 13	13.10	15.70	13.40	15.90	13.60	15.30	12.80	14.00	13.50	14.85
Average	13.75	16.26	13.59	15.60	14.02	15.10	13.49	14.45	13.19	14.14
Average increase	2.51		2.01		1.08		0.96		0.95	

[1] The wheat milled at mill No. 5 contained about 10 per cent of durum wheat.
[2] No sample obtained.

The lowest moisture content for tempered wheat recorded here is shown to be 13.4 per cent and the highest 16.7 per cent. The former appeared in the case of mill No. 5 and the latter in the case of mill No. 1. The average moisture content for the five mills ranged from 14.14 per cent for mill No. 5 to 16.26 for mill No. 1.

The average increase in moisture content resulting from tempering for the period indicated is shown to have been 2.51 per cent for mill No. 1; 2.01 per cent for mill No. 2; 1.08 per cent for mill No. 3; 0.96 per cent for mill No. 4; and 0.95 per cent for mill No. 5. From these results it appears that a diversity of opinion existed among the millers of these mills as to the amount of moisture hard red winter wheat should contain in order to be properly tempered.

MOISTURE CONTENT OF WHEAT AND VARIOUS STREAMS OF MILL STOCK.

Table II shows the moisture content of the different streams of mill stock and the yield of the various commercial products of three large mills. The arranging of the data in this table was difficult because of the dissimilarity of the processes used at the three mills. The system of separating and grading the stock for subsequent reduction at certain steps was not carried out to an equal extent for all the mills; consequently, certain streams of stock found in one mill were not found in the others nor were streams of stock bearing the same name always of similar character.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data.*

PART 1.—*Effect of the process of preparation for milling upon the moisture content of the wheat.*

Wheat.	Mill No. 1, hard red winter.	Mill No. 2, hard red winter.	Mill No. 3, soft red winter.
	Per cent.	*Per cent.*	*Per cent.*
Moisture content before cleaning and tempering	12.40	13.90	14.04
Moisture content after cleaning and tempering	16.00	13.80	14.67
Effect on moisture content of cleaning and tempering	3.60 gain.	.10 loss.	.63 gain.

PART 2.—*Moisture content of the various roll streams before and after grinding, and the loss or gain in that factor resulting therefrom.*

Stream.	Mill No. 1.			Mill No. 2.			Mill No. 3.		
	Moisture content.		Effect of grinding on moisture content.	Moisture content.		Effect of grinding on moisture content.	Moisture content.		Effect of grinding on moisture content.
	Before grinding.	After grinding.		Before grinding.	After grinding.		Before grinding.	After grinding.	
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
First break	16.00	15.27	0.73 loss.	13.80	13.90	0.10 gain.	14.67	14.78	0.11 gain.
Second break	15.46	15.23	.23 loss.	14.19	13.85	.34 loss.	15.15	14.90	.25 loss.
Second break chunk	15.26	14.75	.51 loss.	.....	.....	.....	.....	.....	.....
Third break	15.73	15.08	.65 loss.	14.02	13.35	.67 loss.	15.06	14.67	.39 loss.
Third break chunk	15.16	14.82	.34 loss.	.....	.....	.....	.....	.....	.....
Fourth break	15.44	14.82	.62 loss.	14.42	13.83	.59 loss.	14.82	14.72	.10 loss.
Fourth break chunk	14.96	14.53	.43 loss.	.....	.....	.....	.....	.....	.....
Fifth break	15.33	(1)	.....	13.73	13.88	.15 gain.	14.37	14.26	.11 loss.
Sixth break	14.96	14.61	.35 loss.	.....	.....	.....	14.19	14.12	.07 loss.
First sizings	13.83	13.48	.35 loss.	13.74	13.72	.02 loss.	13.24	12.65	.59 loss.
Second sizings	13.91	13.55	.36 loss.	13.94	13.43	.51 loss.	14.06	13.56	.50 loss.
Third sizings:									
Grade (*a*)	13.55	13.28	.27 loss.	12.73	12.14	.59 loss.	.....	.....	.....
Grade (*b*)	13.34	13.03	.31 loss.	.....	.....	.....	.....	.....	.....
Third break sizings	.....	.....	.....	13.00	12.53	.47 loss.	.....	.....	.....
First middlings:									
Grade (*a*)	14.16	13.48	.68 loss.	14.00	13.64	.36 loss.	13.75	13.48	.27 loss.
Grade (*b*)	13.50	13.14	.36 loss.	13.58	13.40	.18 loss.	13.23	12.93	.30 loss.
Grade (*c*)	13.93	13.53	.40 loss.	13.33	13.27	.06 loss.	13.87	13.64	.23 loss.
Grade (*d*)	13.42	13.28	.14 loss.	.....	.....	.....	.....	.....	.....
Grade (*e*)	12.81	12.77	.04 loss.	.....	.....	.....	.....	.....	.....
Grade (*f*)	13.44	13.39	.05 loss.	.....	.....	.....	.....	.....	.....
Second middlings:									
Grade (*a*)	13.79	13.41	.38 loss.	13.69	13.32	.37 loss.	13.11	12.75	.36 loss.
Grade (*b*)	13.27	12.99	.28 loss.	13.30	12.89	.41 loss.	12.82	12.28	.54 loss.
Grade (*c*)	.....	.....	.....	.....	.....	.....	13.68	13.37	.31 loss.
Second middlings granulator	12.93	12.47	.46 loss.	.....	.....	.....	.....	.....	.....
Third middlings:									
Grade (*a*)	12.93	11.73	1.20 loss.	13.24	12.90	.34 loss.	13.14	12.80	.34 loss.
Grade (*b*)	12.94	11.75	1.19 loss.	.....	.....	.....	.....	.....	.....
Third middlings granulator	13.69	13.27	.42 loss.	.....	.....	.....	.....	.....	.....
Fourth middlings:									
Grade (*a*)	13.20	13.07	.13 loss.	12.67	12.65	.02 loss.	12.45	12.19	.26 loss.
Grade (*b*)	12.67	12.38	.29 loss.	.....	.....	.....	.....	.....	.....
Fifth middlings:									
Grade (*a*)	12.63	12.04	.59 loss.	12.39	11.78	.61 loss.	12.24	11.38	.86 loss.
Grade (*b*)	13.15	12.70	.45 loss.	.....	.....	.....	.....	.....	.....
Sixth middlings	11.68	11.15	.53 loss.	.....	.....	.....	11.89	11.08	.81 loss.
Seventh middlings	12.42	12.01	.41 loss.	.....	.....	.....	12.56	11.80	.76 loss.
First tailings:									
Grade (*a*)	13.00	12.70	.30 loss.	12.81	12.51	.30 loss.	12.01	11.59	.42 loss.
Grade (*b*)	13.32	13.17	.15 loss.	13.36	12.83	.53 loss.	.....	.....	.....
Second tailings:									
Grade (*a*)	12.40	12.23	.17 loss.	12.89	12.18	.71 loss.	12.37	11.73	.64 loss.
Grade (*b*)	.....	.....	.....	12.23	12.04	.19 loss.	.....	.....	.....
Third tailings	12.97	13.22	.25 gain.	12.55	12.06	.49 loss.	11.82	11.75	.07 loss.
First low grade	11.85	11.18	.67 loss.	12.16	11.83	.33 loss.	11.41	10.98	.43 loss.
Second low grade	11.20	11.05	.15 loss.	12.18	11.86	.32 loss.	.....	.....	.....
Third low grade	11.17	11.00	.17 loss.	.....	.....	.....	.....	.....	.....

[1] No sample obtained.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data*—Continued.

PART 2.—Continued.

Average loss in moisture content of stock resulting from grinding

	Mill No. 1.	Mill No. 2.	Mill No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Average for breaks	0.482	0.270	0.135
Average for reductions	.367	.358	.452
Average for all	.392	.340	.370

PART 3.—*Moisture content of the flour resulting from the different grinding operations.*

Flour.	Mill No. 1.	Mill No. 2.	Mill No. 3.
	Per cent.	*Per cent.*	*Per cent.*
First break	13.73	[1] 13.55	14.25
Second break	14.65	[2] 13.50	14.39
Second break chunk	.....	.....	.....
Third break	14.11	.....	14.21
Third break chunk	.....	.....	.....
Fourth break	14.10	.....	14.39
Fourth break chunk	.....	.....	.....
Fifth break	13.68	[3] 12.67	14.16
Sixth break	[4] 12.21	.....	13.92
First sizings	12.95	13.61	12.71
Second sizings	.....	13.21	13.77
Third sizings:			
Grade (a)	.....	12.45	.....
Grade (b)	12.88	.....	.....
Third break sizings	.....	12.12	.....
First middlings:			
Grade (a)	12.80	12.72	13.16
Grade (b)	.....	.....	13.09
Grade (c)	.....	.....	13.54
Grade (d)	.....	.....	.....
Grade (e)	.....	.....	.....
Grade (f)	.....	.....	.....
Second middlings:			
Grade (a)	12.46	12.92	13.46
Grade (b)	.....	.....	.....
Grade (c)	.....	.....	.....
Second middlings, granulator	.....	.....	.....
Third middlings:			
Grade (a)	12.16	12.95	12.59
Grade (b)	.....	.....	.....
Third middlings, granulator	.....	.....	.....
Fourth middlings:			
Grade (a)	12.34	12.24	12.17
Grade (b)	.....	.....	.....
Fifth middlings:			
Grade (a)	12.05	11.96	[5] 11.96
Grade (b)	.....	.....	.....
Sixth middlings	11.31	.....	[6] 12.24
Seventh middlings	11.92	.....	[7] 12.15
First tailings:			
Grade (a)	12.87	12.05	11.25
Grade (b)	.....	12.87	.....
Second tailings:			
Grade (a)	12.08	12.18	12.68
Grade (b)	.....	12.02	.....
Third tailings	[8] 13.02	11.90	.....
First low grade	11.23	11.70	11.11
Second low grade	11.53	11.77	.....
Third low grade	11.05	.....	.....

[1] Includes flour from fourth break.
[2] Includes flour from third break.
[3] Includes flour from shorts duster and tail of rebolter.
[4] Includes flour from bran duster.
[5] Includes flour from third tailings.
[6] Includes flour from bran duster.
[7] Includes flour from shorts duster.
[8] Includes flour from sizings duster.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data*—Continued.

PART 4.—*Moisture content and relative milling yields of the different commercial products of each mill.*

Product.	Mill No. 1.		Mill No. 2.		Mill No. 3.	
	Moisture content.	Milling yield.	Moisture content.	Milling yield.	Moisture content.	Milling yield.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Patent flour	12.12	45.99	12.97	51.30	13.32	31.44
Clear flour	12.88	21.23	13.01	17.70	[3] 13.22	41.83
Low grade flour	12.30	3.54	12.39	3.90	.....	.....
Red dog	.....	.....	11.70	1.00	.....	.....
White shorts	[1] 10.40	3.86	.....	.....	[1] 11.41	3.00
Brown shorts	13.28	11.26	[2] 12.28	10.80	12.15	8.23
Bran	14.24	14.12	13.95	15.30	14.19	15.50
Total	.....	100.00	.....	100.00	.....	100.00

[1] Includes red dog. [2] Includes white shorts. [3] Includes low grade flour.

PART 5.—*The calculated gain or loss in weight resulting from the addition or evaporation of moisture during the cleaning, tempering, and milling processes.*

Product and effect of treatment.	Mill No. 1.		Mill No. 2.		Mill No. 3.	
	Moisture content.	Relative[1] weight.	Moisture content.	Relative[1] weight.	Moisture content.	Relative[1] weight.
	Per cent.		*Per cent.*		*Per cent.*	
Uncleaned and untempered wheat	12.40	100.00	13.90	100.00	14.04	100.00
Cleaned and tempered wheat	16.00	104.29	13.80	99.88	14.67	100.74
Mill products	12.65	100.29	13.02	98.99	13.26	99.10
Effect of cleaning and tempering on weight of wheat	*Per cent.* 4.29 gain		*Per cent.* 0.12 loss		*Per cent.* 0.74 gain	
Effect of milling process on weight of wheat	3.84 loss		0.91 loss		1.63 loss	
Combined effect of cleaning, tempering, and milling processes on weight of untempered wheat	0.29 gain		1.01 loss		0.90 loss	

[1] Base 100.00—untempered wheat.

EFFECT OF TEMPERING UPON THE MOISTURE CONTENT OF WHEAT.

The difference between the moisture content of wheat before and after cleaning and tempering, shown in part 1 of Table II, was, in the case of mill No. 1, an increase of 3.60 per cent; mill No. 2, a decrease of 0.10 per cent; and mill No. 3, an increase of 0.63 per cent. The lack of uniformity in tempering among these mills can be accounted for partly by the fact that the wheat milled at mill No. 1 was of the dry crop of 1914, while that milled at mills Nos. 2 and 3 was of the crop of 1915 and not nearly so dry, consequently requiring the addition of a less amount of moisture in tempering.

It appears odd that in the case of one of the mills, namely, that of mill No. 2, a slight decrease should occur. However, in this particular case, the amount of water added was very slight, and, since under certain conditions the cleaning and scouring of wheat results in the evaporation of a portion of its moisture, it may have happened that the amount lost from this cause exceeded that added at the time of tempering.

DISTRIBUTION OF MOISTURE IN THE TEMPERED WHEAT KERNEL.

An examination of the data of part 2 of Table II shows that as the process of milling progressed from the breaks to the sizings and middlings reductions, and then to the tailings and low grade reductions, the moisture content of the streams of stock on the various rolls became less and less. Figure 1, which gives a graphic representation of the relative amounts of moisture present at the successive steps in the milling process indicated in this part of the table, illustrates this fact more clearly. The curves shown in this figure represent, for each mill, the differences in the moisture content of the various streams of roll stock before grinding.

An interesting point to note in this connection is that the moisture content of the second, third, and fourth break streams in the instance of mills Nos. 2 and 3 was higher than that of the wheat on the first break roll. In the part of the milling process known as the break reductions, there is a gradual reduction of the wheat kernel resulting in a more or less complete separation of the middlings or endosperm particles from the bran. This fact, considered in connection with the point mentioned above, leads to the conclusion that for the cases examined, very little of the water added in tempering penetrated farther than the outer coatings of the kernel.

It is a well-known fact that fifth and sixth break streams are composed of a greater percentage of bran than the preceding breaks, and in accordance with the conclusion just stated, should contain a correspondingly higher percentage of moisture. The results shown here, however, are of a contradictory nature. The probable explanation of this apparent inconsistency is that the loss of moisture through evaporation at the time of grinding and bolting exceeded any increase in the moisture content of such streams caused by the elimination of drier particles.

It is observed also that the roll streams containing the lesser amounts of moisture were those known as the low grades, which streams occur at the extreme end of the milling process. This low-grade stock is composed of very small bran and germ particles together with such endosperm particles as are unavoidably removed with them when the former are separated from the various streams of reduced middlings. The probable reason for their lesser moisture content is the fact that the parts of the kernel composing these streams are subjected to the grinding action of the rolls a greater number of times and, consequently, are exposed to the drying effect of the atmosphere much more than those composing the other streams.

An interesting observation in connection with the data given in parts 1 and 2 of Table II is that, in spite of the relatively great difference among the mills in the moisture content of the wheat at the

beginning of the milling process, a close similarity existed in the amounts of moisture contained in the respective sizings and middlings streams of the three mills.

LOSS OF MOISTURE DURING GRINDING.

The effect of the grinding on the moisture content of wheat and various kinds of roll stock is shown in part 2 of Table II as the differ-

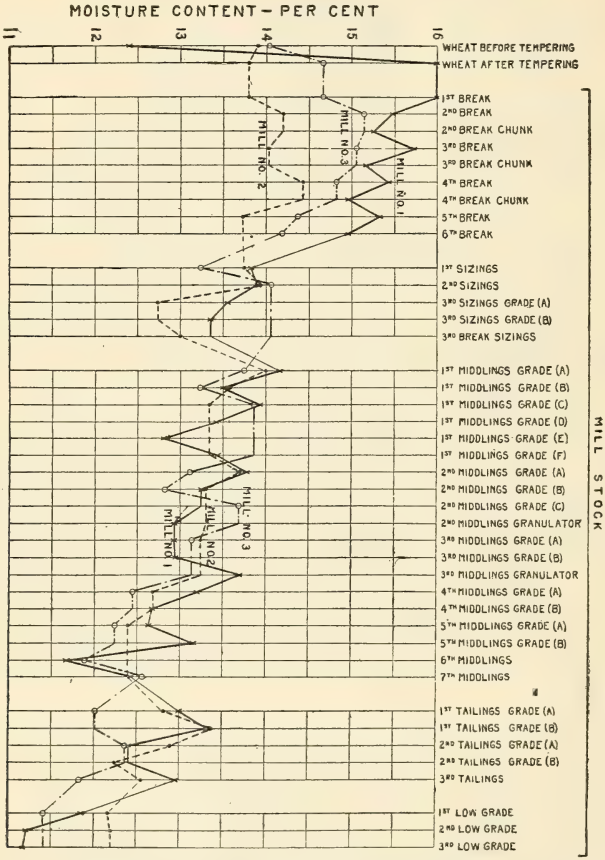

FIG. 1.—Diagram showing differences in the moisture content of streams of mill stock going to the various rolls.

ence between the moisture content of the streams before and after grinding. The average decrease for all grinding operations was 0.392 per cent for mill No. 1; 0.340 per cent for mill No. 2; and 0.370 per cent for mill No. 3. The average decrease, however, among the three mills, for that portion of the grinding operations known as the breaks, varied considerably, being 0.482 per cent for mill No. 1; 0.270 per cent for mill No. 2; and 0.135 per cent for mill No. 3. This wide range between mill No. 1 and the other mills was possibly

due to the higher moisture content of the break streams of mill No. 1. On the other hand, the average decrease for the reductions, or those grinding operations of sizings, middlings, tailings, and low grade stock was 0.367 per cent for mill No. 1; 0.358 per cent for mill No. 2; and 0.452 per cent for mill No. 3; or, in other words, was least for mill No. 1 and greatest for mill No. 3. These differences among the mills in the average decrease of moisture content resulting from grinding

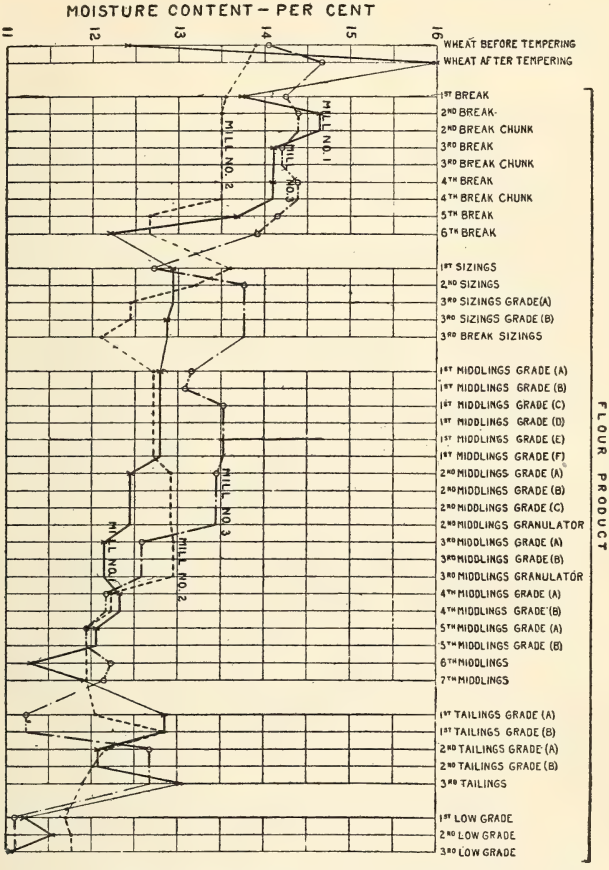

FIG. 2—Diagram showing differences in the moisture content of flour resulting from the various grinding operations.

was probably due in part to variations in methods of milling and in atmospheric conditions at the time of grinding.

Four instances are shown in which the percentage of moisture contained in the roll stream after grinding was greater than before. It is possible that in these instances the samples from which the determinations were made were not representative of the streams sampled, and, therefore, the results obtained do not represent actual conditions. The fact that three of the four instances appeared in connection with

break streams adds weight to this conclusion, especially since it is true that the streams coming from the break rolls are composed of particles differing greatly in size and character, thereby making it difficult to secure a representative sample, or to divide it, for the purpose of moisture determination, into smaller portions composed of the different sizes and character of particles in their proper proportion.

MOISTURE CONTENT OF DIFFERENT FLOUR STREAMS.

Part 3 of Table II shows the percentage of moisture contained in the flour produced by the different grinding, or reduction, operations indicated in part 2.

In practically all mills it is the practice to combine streams of small quantity and similar quality coming from different grinding operations before a separation of the flour product is made. The moisture percentages in some of the instances given here represent the moisture content of the flour product of combined streams, a fact which accounts for some of the apparent omissions and inconsistencies in the table.

Probably the most interesting thing to note from the data given in part 3, as in the case of the data of part 2, is the reduction of the moisture content of the flour streams as the milling proceeded from first break to the end of the process, the break streams being highest and the low grade streams lowest. This point is illustrated more clearly by the curves shown in figure 2.

The flour streams resulting from the break stock of mills Nos. 1 and 3 showed a considerably higher moisture content than did those from the sizings, middlings, tailings, or low grade stock. The moisture content of the break flour of mill No. 2, on the other hand, did not appreciably differ from that of the sizings and middlings flour. This may have been due to the little difference in moisture content among the break, sizings, and middlings roll streams.

Examination of parts 2 and 3 of Table II shows, except with respect to the break flour product of mills Nos. 1 and 3, a close correspondence between the moisture content of the flour product and that of the roll stream from which it was derived. The moisture content of the different break flour streams of mills Nos. 1 and 3, although higher than that of their middlings and sizings flour was, in some instances, as much as 2 per cent lower than that of the break roll streams from which they were produced.

MOISTURE CONTENT AND YIELD OF MILL PRODUCTS.

Part 4 of Table 2 shows the percentage of moisture contained in the different commercial products of each mill together with the percentage of yield of each. The milling yields given here are based upon the actual weights of the products milled during a test run made

at the time the samples were obtained. The duration of the test run was 12 hours for mills Nos. 1 and 2, and 2 hours for mill No. 3. The wide range among the mills shown here in the yields of the different flours has little general significance, because each of these mills, within certain limits, varied the quality of its flour product to meet the requirements of its trade.

It is interesting to note that the moisture content of the patent flour of each mill was lower than that of the untempered wheat. This is even true in the case of mill No. 1, where the increase in moisture content during tempering was as great as 3.60 per cent. This fact further substantiates the conclusion already expressed that very little of the water added to the wheat during tempering penetrated deeper than the pericarp, or branny portion of the kernel.

The moisture content of the clear flour of mills Nos. 1 and 2 is shown to be slightly higher than that of the patent flour. For mill No. 3 the clear and low grade flours were combined; consequently, the moisture content given is not representative of each separately, but is, no doubt, too low for the former and too high for the latter.

Another interesting observation is that the low grade flour, red dog, and white shorts had a lower moisture content than the brown shorts or bran. This further indicates that little of the moisture added during tempering penetrated beyond the pericarp.

GAINS AND LOSSES IN WEIGHT EFFECTED BY CHANGE IN MOISTURE CONTENT INCIDENT TO TEMPERING AND MILLING.

In part 5 of Table II are shown the percentages of weight gained or lost by the addition or evaporation of moisture incident to the tempering and milling processes. The calculation of the relative amounts gained or lost is based on differences in moisture content of the untempered wheat, the tempered wheat, and the mill products. The average moisture content given here of the mill products is calculated from the moisture content and milling yield of the products referred to in part 4.

The change in weight resulting from the change in moisture content of the wheat during cleaning and tempering shows for mill No. 1 a gain of 4.29 per cent, for mill No. 2 a loss of 0.12 per cent, and for mill No. 3 a gain of 0.74 per cent.

The loss in weight of the cleaned and tempered wheat through evaporation of moisture during the process of milling, is shown to have been 3.84 per cent for mill No. 1, 0.91 per cent for mill No. 2, and 1.63 per cent for mill No. 3. These losses show a correspondence to the gains resulting from tempering in that the mill showing the greatest gain during tempering had the greatest loss during milling, and the mill showing the least gain during tempering had the least loss during milling.

The net change in weight due to change in moisture content from the beginning of the tempering process to the end of the milling process was, for mill No. 1, a gain of 0.29 per cent; for mill No. 2, a loss of 1.01 per cent; and for mill No. 3, a loss of 0.90 per cent. From a comparison of all the results given in part 5, it may be concluded that the amount of water added in tempering compensated for the evaporation of moisture during milling only in the case of mill No. 1.

Whether or not the calculated gains and losses given here for each of the three mills agree with the gains and losses ascertained from an actual weighing of the wheat and the products milled therefrom is not known except in the instance of mill No. 1. Calculations made from the daily and weekly reports of this mill giving the scale readings of the wheat before cleaning and tempering, after tempering, and of the products from the packers showed approximately the same results as those given in the table.

In the actual milling of wheat on a commercial scale, the correct percentage of gain or loss resulting from the addition or evaporation of moisture during the tempering and milling processes, whether based on differences in moisture content or in weight, can not be obtained exactly, for the reason that the moisture content is affected by certain variable conditions, and calculations which would be based upon any samples obtained would be incorrect to the extent of their variation from the true average condition. Both the moisture content of the untempered wheat, and the amount of water added during tempering are also likely to vary from time to time, resulting in a proportionate variation in the moisture content of the tempered wheat. Furthermore, any change in the adjustment of the rolls and other machines or in atmospheric conditions may cause a slight variation in the evaporation of moisture and the milling yield of the different products. All such variations necessarily affect the accuracy of the results.

SUMMARY OF RESULTS.

(1) The decrease in the moisture content of the various roll streams from the head to the tail of the milling process was closely related to the amount of water added to the wheat during tempering.

(2) It appeared that very little of the moisture added to the wheat during tempering penetrated farther than the pericarp or outer coatings of the kernel.

(3) The moisture content of the better grades of flour milled, irrespective of the amount of water added during tempering, closely corresponded to the percentage of moisture contained in the untempered wheat.

(4) The amount of water added in tempering compensated for the evaporation of moisture during milling only in the case of one of three mills examined.

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